SUBJECT: Solar Array Vs. Meteoroid/
Asteroid Environment
Case 103-2

DATE: October 11, 1966

FROM: C. E. Johnson
J. D. Dunlop

ABSTRACT

Solar array power degradation, for a 1975-1980 manned Mars flyby mission, resulting from meteoroid/asteroid environments has been briefly investigated. Assuming that the relative mean velocity of asteroids with respect to the spacecraft is less than one half their postulated 20.7 km/sec mean heliocentric velocity, it appears feasible to use solar arrays as a power source. Since the determination of this feasibility is highly dependent on the asteroid flux model, a more realistic estimate of this environment is needed in the region of small particle sizes ($m < 0.1$ grams). Also, since the above feasibility estimate is based on very limited test data, additional work should be performed with regard to crystallographic structure damage and "sand blasting" effects resulting form hypervelocity impact of solar cells.

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MEMORANDUM FOR FILE

Introduction

The feasibility of using a solar array as a power source for a 1975-1980 manned Mars flyby mission is dependent on the amount of power degradation resulting from the meteoroid/asteroid environment. A realistic definition of this environment has not yet been specified due to a lack of sufficient data. Specifically, the asteroidal environment is a matter of serious conjecture since it is currently assumed to be 10^3 times the present Apollo Cislunar Sporadic Meteoroid Model.[1] Further complicating the issue are uncertainities in various penetration theories, solar cell power degradation resulting from hypervelocity impact, and consideration of meteoroid velocities relative to the spacecraft and its orientation. Recent studies at Bellcomm, however, have revealed that the relative mean velocity of asteroids to a Mars flyby spacecraft in the asteroid belt, is less than one half of their postulated 20.7 km/sec mean heliocentric velocity. Understanding that there is a considerable "gray area" associated with presently determining solar array/meteoroid feasibility, it is nevertheless desirable that an attempt be made.

General

Assuming that the asteroidal environment can be approximated by the model shown in figure 1, and that a typical manned Mars flyby 1975-1980 mission spends 240 days in the asteroidal belt, the number of impacts experienced by a 1 x 2 cm. solar cell by spherical asteroids with a density of 3.5 g/cc are shown in Table I.

TABLE I

d (cm.)	d (μ)	NAT (impacts)
0.1	1000	4.95×10^{-5}
0.01	100	4.95×10^{-2}
0.0075	75	0.1175
0.0035	35	1.16
0.0010	10	49.5
0.0005	5	396.0
0.0002	2	6180.0

Tests have been performed to determine solar cell power degradation as a result of particle impact. Referring to John A. Fager's paper on the effects of hypervelocity impact on protected solar cells, it is seen that for spherical glass particles (ρ = 2.2 g/cc) of 35 and 75 μ, an average power degradation of 22.5% occurred after $\gtrsim$ 10 impacts per 1 x 2 cm. cell at 14.8 km/sec.[1] At 27.4 km/sec the power degradation was 55% indicating the effect to be velocity dependent. The current voltage characteristics of the cell changed, indicating a change in the crystallographic structure of the cell (dislocations resulting in a reduced half life of minority charge carriers). Damage to the crystallographic structure is one mode of power degradation; another is the "sand blasting" effect. "Sand blasting" the cover glass of a solar cell reduces the amount of incident solar energy which can be transmitted through the glass into the cell. Recent discussions with Boeing (Seattle), and Arvin Smith (NASA Headquarters), revealed that, based on tests, a power degradation of 15-20% can be expected upon subjecting solar cells to a "sand blasting" environment.

Using the limited test data available, an estimate of solar array power degradation can be made for the asteroidal environment model shown in Figure 1. The number of solar cell impacts of particles greater than 100 μ in diameter, for 240 days in the asteroid belt, is negligible (Table I). According to reference 2, it is seen that none of the 75 μ particles, at velocities up to 27.4 km/sec penetrated the 6 mil. cover glass, and, therefore, it can be assumed that no cover glass penetration will occur from particles less than 100 μ in diameter. Assuming that all particles less than 10 μ in diameter comprise a "sand blasting" environment, crystallographic structure power degradation is a result of impact from particles in the 10-100 μ diameter range. Referring to Table I, the number of solar cell impacts for particles of 10-100 μ in diameter is 0.5-50.0; particles of 35 μ impacting approximately once. Realizing that this is an exponential variation, the data presented in reference 2 provides a reasonable first estimate of the power degradation due to solar cell crystallographic structure damage for the asteroidal environment model in Figure 1.

A power degradation estimate for a solar array is highly sensitive to an assumed asteroidal environment. The asteroid model in Figure 1 was derived by extrapolating backwards from observatory stellar intensity data for extremely large particles ($m > 10^{15}$ Kg) along the slope of the Apollo Sporadic Meteoroid Model. The flux of particles smaller than 100 μ in diameter is, therefore, highly questionable. If, as some scientists contend, the flux for these small particles is no greater than that specified by the Apollo model. The number of solar cell impacts of particles greater than 10 μ in diameter is negligible (NAT = 0.05 for 10 μ diam.), and, therefore, the crystallographic structure power degradation can also be assumed as negligible. Power degradation due to the "sand blasting" effect in the asteroid belt is also reduced. If the Apollo Sporadic Meteoroid Model is assumed to apply throughout the duration of a Mars flyby mission for particles causing this effect, the previous estimate could remain at 15-20%. However, recent results from the Mariner IV Mars flyby spacecraft have indicated that no significant solar panel degradation ($\geq$ 15%) has occurred to date. Therefore, a better estimate for power loss, due to the "sand blasting " effect is 15%.

In summary, an estimate of total power degradation for a solar array used as a power source for a 1975-1980 manned Mars flyby mission ($\approx$ 240 days in the asteroid belt) is shown in Table II for two meteoroid/asteroid models.

TABLE II

Solar Array Power Degradation Estimates

Asteroid Model (Fig. 1)					Apollo Model
Relative Velocity (km/sec)	Complete Destruc. of cell (%)	Crystallographic Structure Damage (%)	Sand Blasting (%)	Total	Total
27.4	1-2	55	15-20	70-75	15
14.8	1	22	15-20	37-42	15
6.0	∿	10	15-20	25-30	15

Conclusions

1. Assuming that the relative mean velocity of asteroids with respect to a 1975-1980 manned Mars flyby spacecraft is less than one half their postulated 20.7 km/sec mean heliocentric velocity, it appears feasible to use solar arrays as a power source for the Mars flyby mission.

2. Since the determination of solar array feasibility for a manned Mars flyby spacecraft is highly dependent on an asteroidal flux model, a more realistic estimate of this environment is needed in the region of small particle sizes ($m < 0.1$ grams).

3. Based on Table II, it appears that, for manned Mars missions, additional work should be done in the area of "sand blasting" effects. However, Table II is based on a questionable asteroid environment and limited test data. Consequently, additional effort should also be performed with regard to the other modes of power degradation.

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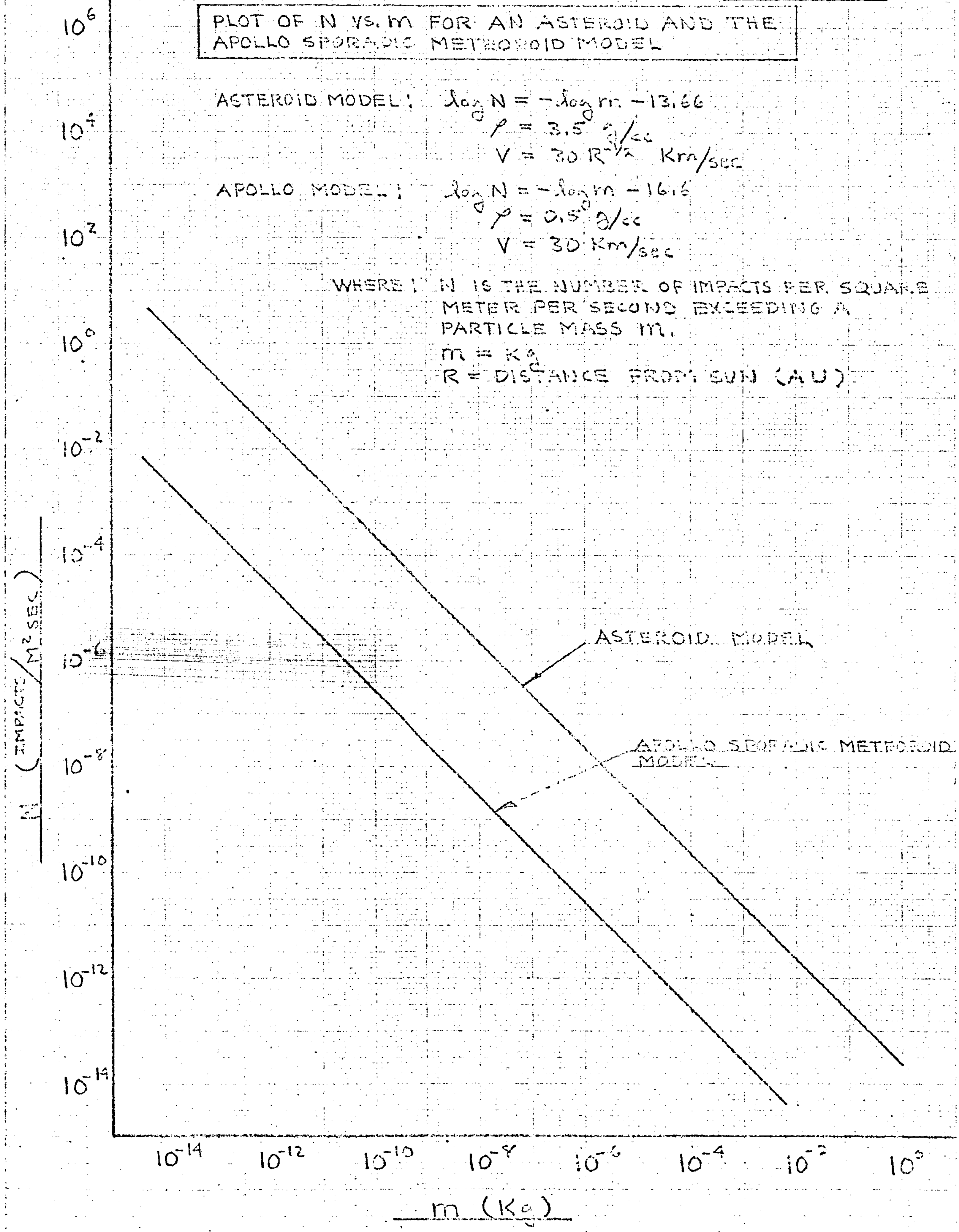
Attachment

REFERENCES

1. Meteoroid Environment Changes to the Apollo Document: "Natural Environment and Physical Standards for the Apollo Program, M-DE 8020,008B (SE015-001-1)," G. T. Orrok, Bellcomm Memorandum, April 18, 1966.

2. Effects of Hypervelocity Impact on Protected Solar Cell, John A. Fager, AIAA Paper No. 65-289, Presented at the AIAA Second Annual Meeting, San Francisco, Cal., July 26-29, 1965.

FIGURE 1



PLOT OF N VS. m FOR AN ASTEROID AND THE APOLLO SPORADIC METEOROID MODEL
ASTEROID MODEL; log N = − log m − 13.66
ρ = 3.5 g/cc
V = 30 R^-1/2 Km/sec
APOLLO MODEL; log N = − log m − 16.6
ρ = 0.5 g/cc
V = 30 Km/sec
WHERE: N IS THE NUMBER OF IMPACTS PER SQUARE METER PER SECOND EXCEEDING A PARTICLE MASS m.
m = Kg
R = DISTANCE FROM SUN (AU)
ASTEROID MODEL
APOLLO SPORADIC METEOROID MODEL
N (IMPACTS/M² SEC)
m (Kg)
10^6
10^4
10^2
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
10^-14
10^-12
10^-10
10^-8
10^-6
10^-4
10^-2
10^0

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